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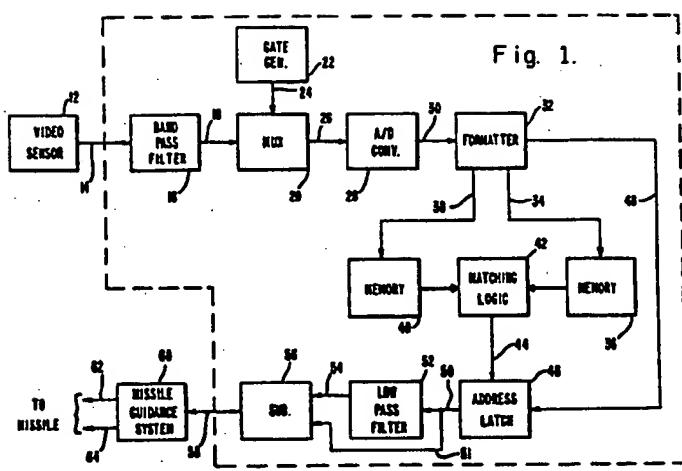
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(54) Jitter compensated scene stabilized missile guidance system.

(57) An improved missile guidance system is provided which automatically compensates for jitter motion of the optical sight of a video tracker. The invention is adapted to receive video data input from an infrared detector or conventional camera (12). The invention includes circuits for filtering, gating, and digitalizing the incoming data as well as a formatter for directing successive frames into memory. Two memories (36, 40) are provided; the contents of which are sampled by matching logic (42) as the second memory is being loaded. The matching logic (42) thereby compares one frame of data to another at plurality of positions and provides a signal to an address latch (46) when the best match is obtained. The format circuitry (32) provides the position information to the address latch where it is stored for further processing. The output of the address latch is filtered to eliminate any signals representative of intentional tracking motion. The filtered output thus provides the jitter correction to the missile guidance system (60) where missile guidance signals are compensated by the jitter correction.

EP 0 064 168 A1

Fig. 1.



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- 1 -

JITTER COMPENSATED SCENE STABILIZED  
MISSILE GUIDANCE SYSTEM

1

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to missile guidance systems.  
More specifically, this invention relates to improvements  
5 in the guidance of line-of-sight commanded missiles.

While the present invention is described herein  
with reference to particular embodiments and applications,  
it is to be understood that the invention is not limited  
thereto. Modifications may be made within the teachings  
10 of this invention without departing from the true spirit  
and scope thereof.

2. Description of the Prior Art

A typical line-of-sight guided missile system  
includes a launcher and a guided missile. The launcher  
15 typically includes a gunner's optical sight and an  
electronic guidance computer which automatically sends  
steering commands to the missile in flight. After  
launch, a beacon in the tail of the missile is activated  
and subsequently detected by a sensor on the launcher.  
20 The sensor is bore sighted with the gunner's telescope,  
and allows the operator to track the missile along  
its flight path. The sensor and associated processing  
circuitry measures the angle between the flight direction  
of the missile and the gunner's line-of-sight. These  
25 displacements are transformed by a computer into  
guidance commands which are sent to the missile over

1 the command link. The gunner need only keep the cross-hairs of the sight on the target during missile flight.

5 Unfortunately, in an actual hostile operational environment, the operator may experience nervous jitters which would tend to impair his ability to maintain the cross-hairs on the center of the target's most vulnerable aim point. If the operator jitters the sensor line-of-sight, the missile tracker would measure a corresponding apparent missile off-set. As it corrected 10 the nonexistent off-set, it would create perturbations which would appear as noise in the missile guidance signals. This would detract from the hit-accuracy of the guidance and tracking system.

15 SUMMARY OF THE INVENTION

The present invention provides means for improving the performance of line-of-sight commanded missile guidance systems.

20 The present invention utilizes a video sensor for providing successive frames of data corresponding to at least a portion of a video scene as viewed by the operator through an optical sight. Signal processing circuitry is provided for analyzing the frames of data to provide electrical signals indicative of the jitter motion of the optical sight relative to stationary objects in the video scene.

25 More specifically, the present invention includes means for converting information representative of the video scene into a train of discrete signals. Successive frames of discrete data are then compared on a pixel by pixel basis until a best match is obtained. (A "pixel" is an individual picture element.) The address at which the best match is obtained provides information indicative of the jitter motion of the tracking system. (The "address" 30 is the reference in number of rows and columns in each frame.) Data must be successively displaced to achieve 35

- 1 the best match to a prior frames reference (or address). This information is then utilized to off-set the jitter motion effect on the missile guidance signals.

5

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic representation of a preferred embodiment of the invention.

- 10 FIG. 2 is representative of the processing of a first frame of video data by the system of the present invention.

FIG. 3 is representative of the processing of a second frame of video data by the system of the present invention.

- 15 FIG. 4 illustrates the method by which successive frames of data are compared by the system of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

- 20 This invention substantially eliminates the effect of gunner jitter by initially tracking arbitrary portions of the background of a video scene remote from the target. The basis for estimating the gunner jitter is the apparent motion of the stationary scene. By measuring how elements 25 of the scene, remote from the target, appear to be moving, gunner jitter may be estimated. The estimation is represented by electrical signals which are subtracted from the missile guidance signals so that the normally occurring gunner jitter is suppressed.

- 30 FIG. 1 shows a block diagram representing of a digital system designed to suppress gunner jitter. It should be noted that while a digital system is disclosed, the principals of the present invention may be realized through equivalent analog

1     circuitry. The gunner jitter suppression circuit is shown  
at 10 in FIG. 1. The suppression system 10 is adapted to  
receive video data from a video sensor 12. The video  
sensor 12 may be a forward looking infrared (FLIR) sensor  
5     or an electronic T.V. camera. The video sensor block  
would also include a display and/or an optical sight  
through which the operator may view the video scene. The  
video output of sensor 12 appears on line 14 and is input  
to the bandpass filter 16. The bandpass filter 16 is  
10    effective as a differentiator to transform the video data  
so that subsequent correlations may be more easily  
measured and identified. The effect of differentiation  
is to delineate scene boundaries. The processing scheme  
15    of the present invention utilizes boundary change infor-  
mation to estimate gunner jitter.

16    The output of the bandpass filter 16 provides  
one input to a multiplexer 20 via line 18. The second  
input to the multiplexer 20 is provided by the gate  
generator 22 via line 24. The multiplexer 20 and  
20    gate generator 22 operate on the analog video output  
of the filter in such a way as to pass data representing  
portions of the video scene remote from the center  
of the field of view. Thus, gated video appears at  
the output of multiplexer 20 on line 26 and is input  
25    to an analog-to-digital (A/D) converter 28.

26    The A/D converter 28 thresholds the video data  
to produce a mosaic of 1's and 0's. See FIGS. 2 and  
3. This stream of binary video is input to a formatter  
32 via line 30. The formater 32 directs video data  
30    into a first memory 36 via line 34 until a first  
frame of gated video is stored. Similarly, video  
data is subsequently formatted into a second memory  
40 via line 38.

1 FIGS. 2 and 3 illustrate the processing of the data  
up to this point. FIG. 2a shows that the first frame of  
data appears at the output of video sensor 12 as raw video.  
The upper portion of the figure illustrates a portion of a  
5 typical video scene with the background clutter represented  
as a shaded area. The filtered video for the corresponding  
line of data is represented in the lower portion of the  
figure as a pulse two units wide.

10 FIG. 2b is illustrative of the same video bandpassed  
by filter 16. The upper portion of the figure now shows  
the boundaries as shaded areas while the lower portion of  
the figure is representative of the derivative of the pulse  
in FIG. 2a.

15 FIG. 2c shows the same portion of the video scene  
at the output of the analog-to-digital converter 28.  
Shaded portions are represented by 1's; the remaining  
portions are represented by 0's. FIG. 2c is thus a mosaic  
of 1's and 0's. Formator 32 provides the formatted video  
of frame 1 to memory 36 in a format typified in FIG. 2d.

20 FIG. 3 illustrates that the second frame of data  
corresponds to a jitter motion effective to displace the  
sensor one element to the left. Note that the raw video  
of FIG. 2a is now moved to the right by one unit as illus-  
trated in FIG. 3a. Subsequent filtering, digitalizing,  
25 and formating, in the manner described above, yields a  
displacement of one unit to the right of the 1's in the  
data stream associated with line 3 of FIG. 3d.

20 Video detector 12, bandpass filter 16, multiplexer  
22, gate generator 22, analog-to-digital converter 28,  
30 and formator 32 thus provide successive frames of video  
data for processing in the manner described below.

35 Returning now to FIG. 1, the information  
stored in memories 36 and 40 is compared by matching  
logic 42. The matching logic may be provided  
by a computer or other digital or analog circuitry.

1        After frame 1 is loaded in memory 36, matching logic  
42 samples frame 2 as it is being formatted into memory.  
The data in memory 40 is sampled and compared at every  
5        step or pixel. The location which gives the best overall  
match is referenced to the last frame's location in order  
to compute incremental motion. The process is illustrated  
in FIG. 4.

FIG. 4a shows that at position N-1 there are 21  
pixels which match and 4 pixels which do not match. The  
10      X's indicate "don't cares". FIG. 4b illustrates that the  
data has marched one position in time to where the number  
of matches is 25. FIG. 4b thus illustrates position N.  
FIG. 4c illustrates position N+1 where the number of  
15      matches is once again 21. Position N therefore provides  
the best match and indicates the displacement of the scene  
due to gunner jitter to be one pixel to the left.

When matching logic detects the best match, it  
signals address latch 46 via line 44. At that point the  
address latch interrogates the formatter 32 to determine  
20      and store the position at which the best match is obtained.  
This information appears on line 48. The address latch 46  
thus provides on line 50 information containing the jitter  
for say the ith sample or  $J_i$ .

Memories 36 and 40, matching logic 42, and address  
25      latch 46 thus provide means for analyzing successive  
frames of video data to provide signals indicative of  
jitter motion of the tracker relative to the video scene.

What remains is to determine whether the incre-  
mental motion is in fact jitter motion or tracking  
30      motion. That is, scene stabilization must be selective.  
It must reduce effects of operator jitter while permit-  
ting accurate tracking of moving targets. Low-pass  
filter 52 and subtractor 56 serve to provide this  
function. The solution to this problem as afforded

1 by the low-pass filter 52 and the subtractor 56 is  
 best illustrated by Equation 1.

$$5 \quad [1] \quad C_i = J_i - \frac{\sum_{x=i-n}^i J_x}{n}$$

Where  $C_i$  is the  $i$ th correction corresponding to the  $i$ th frame and  $J_i$  is the  $i$ th jitter sample. Equation 1 illustrates that the jitter correction 10  $C$  for a given frame  $i$  is equal to the difference between the incremental jitter sample  $J_i$  and the

$$\frac{\sum_{x=i-n}^i J_x}{n}$$

average of the previous  $n$  jitter samples  $x=i-n$ .

15 Address latch 46 provides  $J_i$  to low-pass filter 42 via line 50 and to subtractor 56 via line 51. Low-pass filter 52 provides the average of the previous jitter samples to the subtractor on line 54. The output 20 of the subtractor on line 58 is the correction  $C$  for a frame  $i$ .

25 Equation 1 can be verified functionally when one considers that in a situation where the gunner is in fact causing the tracker to undergo jitter, the effect of the jitter maybe sinusoidal in nature. As a result, its average would be zero and the correction would equal the  $i$ th jitter sample. However, when the operator is tracking a target, the tracker position does not vary as a sinusoid but more as a ramp. The average behavior of 30 a filtered ramp is another ramp delayed in time. Thus the corresponding correction would be the jitter which rides on the ramp. The filtered ramp is subtracted from this to leave a small value relative to the missile guidance signals.

1        It should be noted here that the solution to the  
jitter/tracking ambiguity of FIG. 1 is illustrative of but  
one of several possible approaches to the problem. Another  
approach would be to utilize a high-pass filter to simply  
5      filter out the signals corresponding to the low frequency  
tracking motion of the tracker. Yet another approach  
would be to utilize an algorithm implemented by a micro-  
processor such as that which may be provided by the missile  
guidance system 60. The use of the low-pass filter and  
10     subtraction technique is preferred in so far as low-pass  
filters appear to function better as integrators than  
high-pass filters function as differentiators.

15     The correction signal C is ultimately provided  
to the missile guidance system 60 via line 58 where  
it is subtracted from the missile guidance commands  
appearing on line 62 and 64.

20     Thus, the low-pass filter 52, subtractor 56 and the  
missile guidance system provides means for compensating  
the missile guidance signals as a function of the jitter  
correction signals to provide signals for effectively  
guiding the missile notwithstanding jitter motion of the  
tracker.

25     The present invention has been described with refer-  
ence to a particular embodiment and a particular appli-  
cation. It is contemplated that modifications may be  
made by those having ordinary skill in the art and access  
to the teachings disclosed herein which are encompassed  
within the principles of this invention. For example,  
systems which include image intensifiers, scan converters,  
30     or vidicons can be adapted to use this same correction  
technique for image-motion compensation. It is thus con-  
templated by the appended claims to cover any and all such  
modifications and applications.

- 1 -

CLAIMS

What is Claimed is:

- 1        1. In a missile guidance system including tracking means and means for providing first signals for guiding a missile to a target, an improvement comprising:
  - 5            means for providing successive frames of data corresponding to at least a portion of a video scene as viewed by said tracking means;
  - means for analyzing said frames of data and providing second signals indicative of jitter motion of said tracking means relative to said video scene; and
  - means for compensating said first signals as a function of said second signals to provide signals for effectively guiding said missile notwithstanding any jitter motion of said tracking means.
- 1        2. The missile guidance system of Claim 1 wherein said means for providing successive frames of data corresponding to a video scene includes detector means for detecting optical energy and providing a corresponding electrical output and means for storing said successive frames of data.
- 1        3. The missile guidance system of Claim 1 wherein said means for analyzing successive frames of data includes means for correlating successive frames of data and means for storing an electrical signal representative of incremental motion of said tracking means when successive frames correlate.

- 2 -

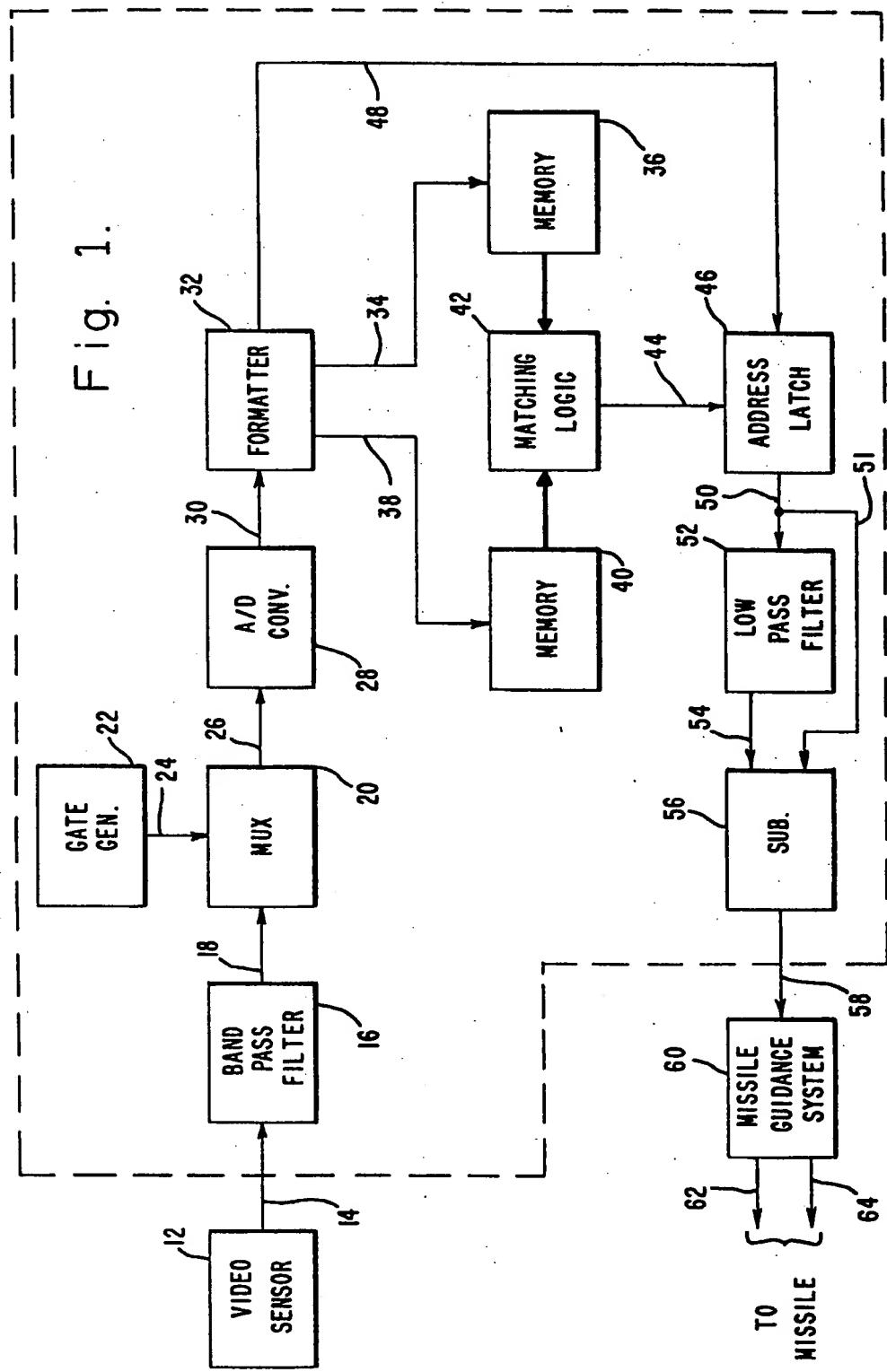
1        4. The missile guidance system of Claim 1  
wherein said means for compensating said first signals  
includes means for discriminating between jitter  
noise and tracking signals.

1        5. The missile guidance system of Claim 4  
wherein said means for discriminating between jitter  
noise and tracking signals includes means for  
averaging the output of said means for storing an  
5        electrical signal representative of incremental motion  
of said tracking motion means and means for subtracting  
said average from the instantaneous output of said means  
for storing electrical signal representative of the  
incremental motion of said tracking means.

1        6. A missile guidance system comprising:  
            means for detecting optical energy and  
providing video data;  
            first filter means for differentiating  
5        said video data to provide filtered output signals;  
            gating means for selecting predetermined  
filtered output signals to provide a gated output;  
            converter means for transforming said  
gated output to digital signals;  
10        means for formating said digital signals  
to provide successive frames of video data;  
            means for storing said successive frames  
of video data;  
            means for comparing said successive frames  
15        of video data at a plurality of relative positions to  
provide an electrical signal indicative of the position  
at which said frames provide a maximum correlation;

- 3 -

- means for storing said electrical signal  
corresponding to the position at which said frames  
20 provide a maximum correlation to provide an electrical  
signal indicative of the incremental motion of said  
means for detecting optical energy;
- means for processing said electrical  
signal corresponding to incremental motion of said  
25 means for detecting optical energy to discriminate  
between signals corresponding to jitter motion and  
signals corresponding to tracking motion; and
- means for compensating missile guidance  
signals to correct for noise resulting from jitter  
30 motion of said means for detecting optical energy.



2/3

Fig. 2.

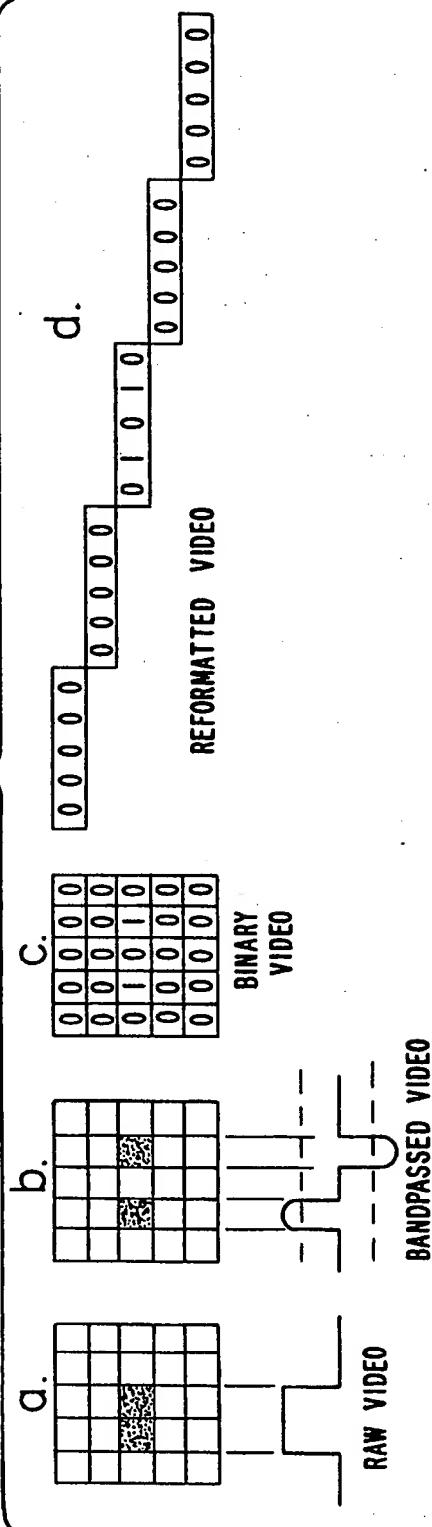
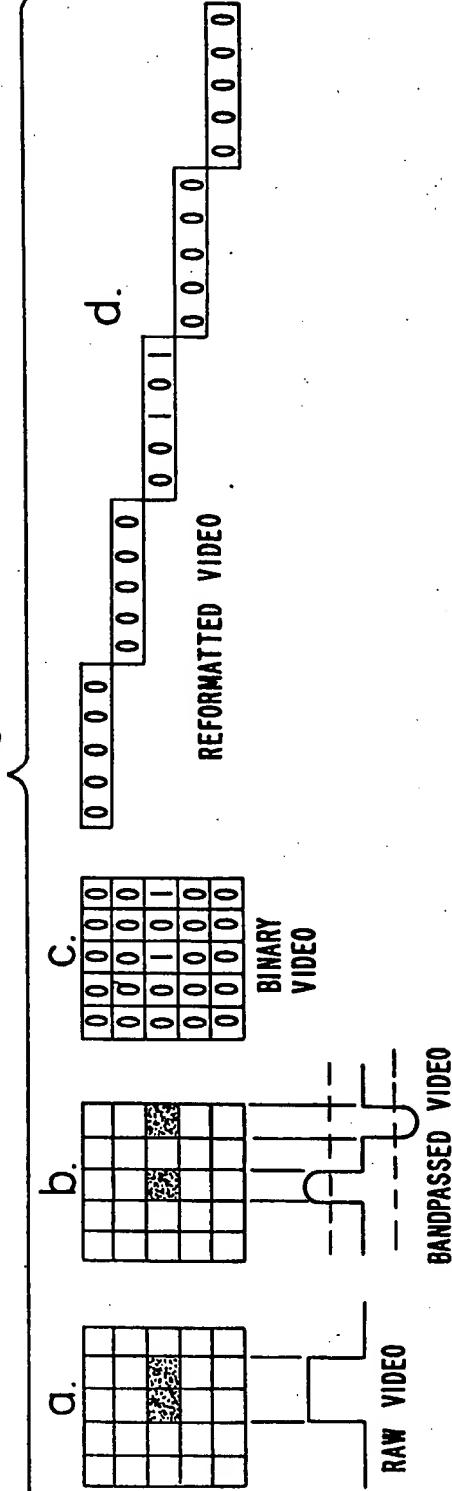


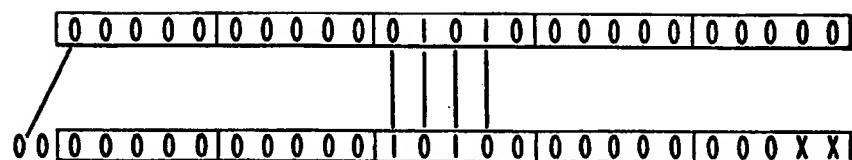
Fig. 3.



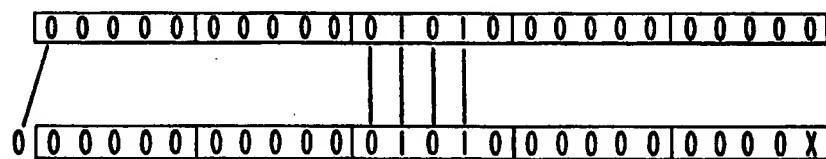
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3/3

a.



b.



c.

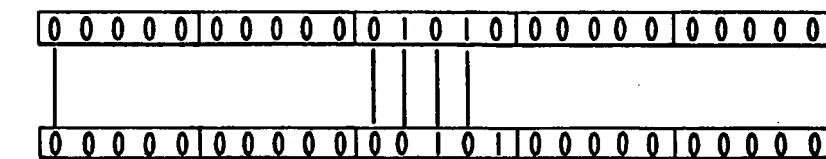


Fig. 4.



European Patent  
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## EUROPEAN SEARCH REPORT

**0064168**

Application number

EP 82 10 2966

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 5)
Y	US-A-4 247 059 (J.R.DUKE et al.) *The whole document*	1-6	F 41 G 7/30
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Y	US-A-4 220 967 (L.F.ICHIDA et al.) *Column 1, line 20 to column 2, line 5; column 3, line 4 to column 4, line 20; figure 1*	1-6	
	---		
A	US-A-3 233 847 (A.GIRSBERGER) *The whole document*	1,4,5	
	---		
A	US-A-3 274 552 (G.L.HARMON et al.) *The whole document*	1,4,5	
	---		
A	GB-A-1 299 851 (BRITISH AIRCRAFT CORP) *Page 1, lines 51-61*	1	TECHNICAL FIELDS SEARCHED (Int. Cl. 5)
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A	US-A-3 829 614 (S.H.AHLBOM et al.)		F 41 G G 01 S
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A	US-A-3 885 453 (H.P.HIGGINSON et al.)		
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The present search report has been drawn up for all claims			
Place of search	Date of compilation of the search	Examiner	
THE HAGUE	10-08-1982	VAN WEEL E.J.G.	
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone	T : theory or principle underlying the invention		
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